CENTRE NATIONAL D'ÉTUDES SPATIALES

43rd ARGOS OPSCOM

New London, USA
June 2009

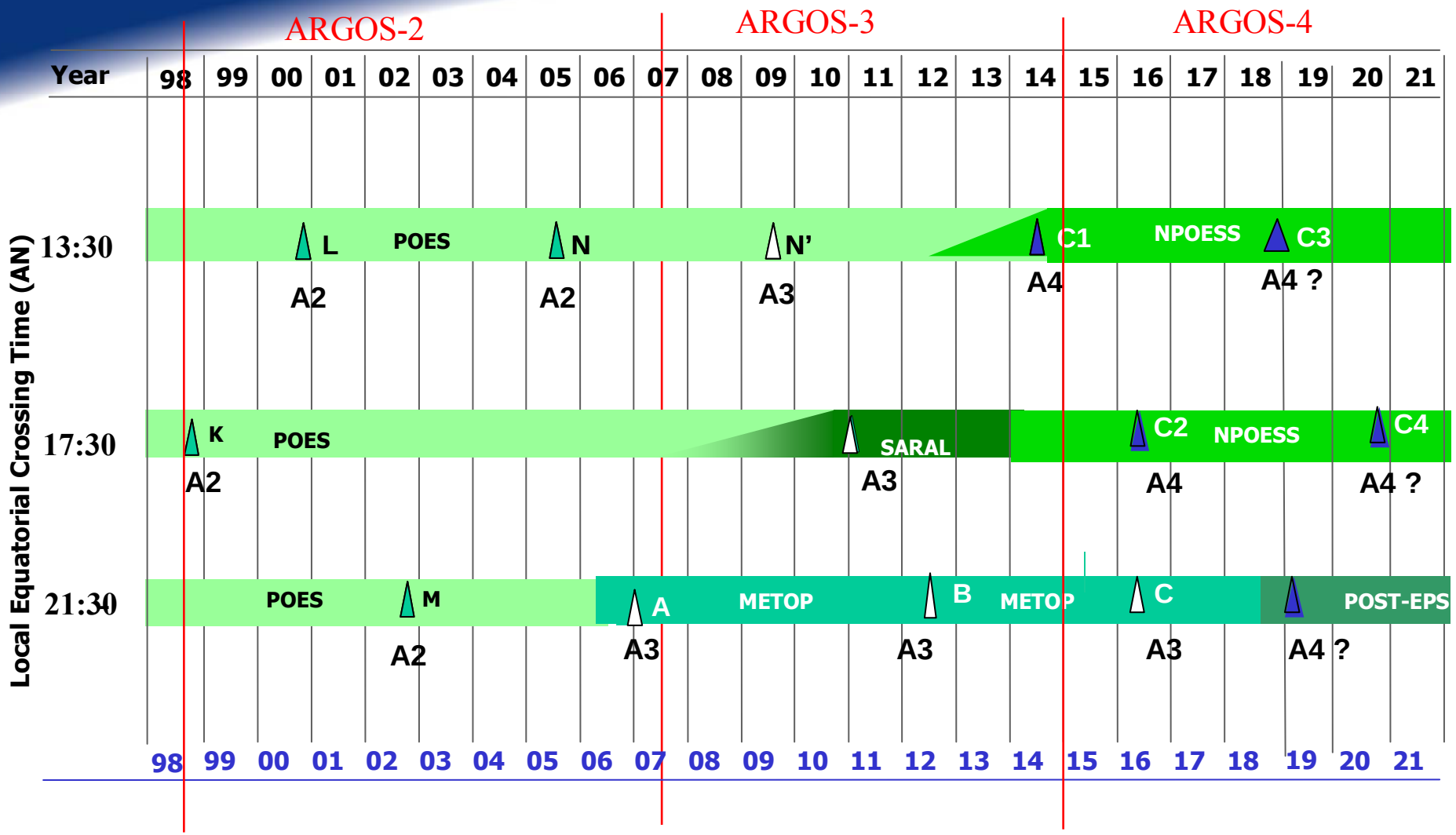
E3 – Argos DCS-4 / NPOESS

Overview

Mid-2005 to mid-2007 : definition of Argos-4 Mission

- Phase 0/A completed by CNES between June 2007 and April 2008
- June 2008 : Final version of MRD submitted at Opscom 2008
- 1st July 2008 : kick-off of feasibility phase (Phase B) with Thales SA
- 2 October 2008 : Argos-4 Project formally decided by CNES Administration Board (Phases B/C/D)
- 8 November 2008 : Implementing Arrangement signed between NOAA and CNES
- 17 February 2009 : Final frequency coordination meeting in Geneva (CGMS)
- 24-25 March 2009 : Argos-4 PDR in CNES
- 28 May 2009 : PDR Complement (downlink frequency, instrument performance with LEON processor, ASIC development plan)
- 10 June 2009 : CNES Board for Argos-4 PDR
- 1st July 2009 : kick-off of Phase C (development phase)

Argos System: the 3 generations



The Argos-4 System

- **Two main objectives :**
  - **To ensure the location and data collection mission continuity on meteorology polar satellites over the period 2014-2022.**
  - **To improve the Service offered to the users, to fullfil their needs until 2022 (more than 30000 Argos platforms are expected from 2015).**
- **Cooperation scheme :**
  - **Agreement with NOAA to embark Argos-4 instruments on-board NPOESS-C1 (mar 2014; AN 13h30) and NPOESS-C2 (june 2016; AN 17h30).**
  - **Embarkment on NPOESS-C3 (2018) and C4 (2020) could be decided in 2010/2011.**
  - **Preliminary discussions with Eumetsat to embark Argos 4 instruments on the future Post-EPS satellites (polar orbite AN at 21h30) from 2018.**

Argos-4 Mission: Requirements

- **Ascending Compatibility**
- **Improvement of System Capacity**
- **Improvement of data amount transmitted every day**
- **Improvement of platform performance**
  - « small terminal » concept is reinforced
  - Specific frequency bands for these « small terminals »
  - Higher sensitivity on board the instrument
  - Decrease of the terminal cost and of the service cost
- **Reinforcement the downlink and the interactive data collection**
- **Continuity of the Argos-3 modes and services**
- **Improvement of Location Performance**
- **Latency Time : this requirement doesn't depend on the instrument but on the satellite constellation.**

I/F with NPOESS

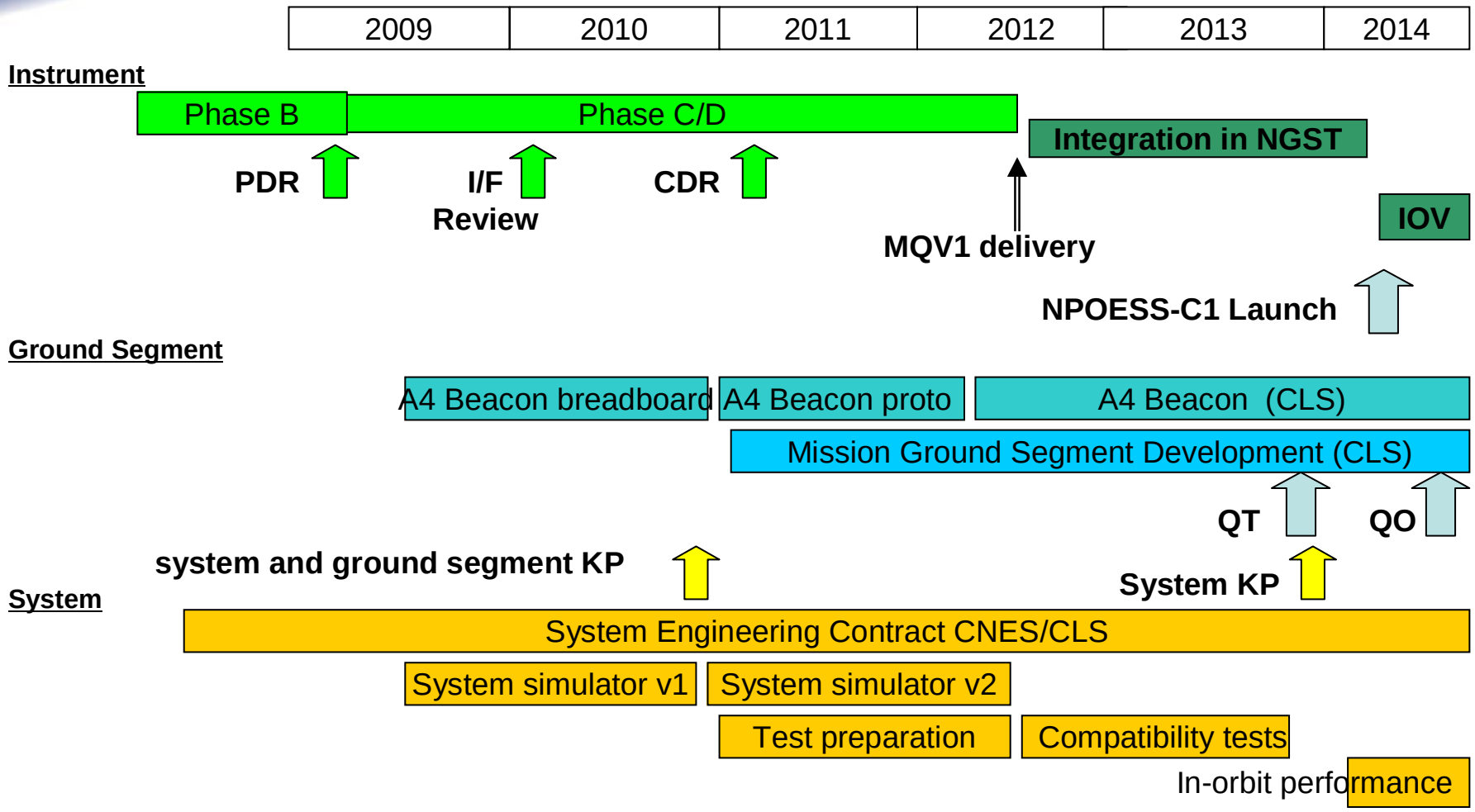
- ICD (Interface Control Document) of the Argos-4 instrument on NPOESS under discussion with Northrop Grumman :
  - preliminary version of ICD provided in May 2007
  - current version B (28/01/08) managed in configuration
  - new revision in July 2008 (after TIM in CNES 9-10-11 July 08)
  - version C agreed, signature expected in June 2009
  - next TIM scheduled in Sept. 09 (ICD, giver list, RF antennas)

- Compliant with main requirements of NPOESS :
  - Mass (RPU+TXU) < 30 kg
  - Power < 82 W (A3 : 57 W) : waiver requested at 90 Watt (84 W nominal)
  - Downlink RF Output Power < 15 W (A3 : 5 W)
  - TM data rate to satellite < 80 kb/s (A3 : 15 kbps)
  - Shock Acceleration : 550 g (A3 : 100g)

I/F with NPOESS : antennas

- Two antennas RX at 401 MHz and TX at 466 MHz to be provided by Northrop with specific requirements at 62° off-nadir
- CNES requires the same level of performance as Tiros or Metop.
- Several discussions with NGST about RF antennas from July 2008 to January 2009 based on simulated performance and difficulties to achieve CNES requirements
- Problem of accommodation on the satellite earth face : degradation of the pattern due to structure interaction
- 95% of the measured points (antenna on the satellite) have to be within the CNES requirement
- Agreement between CNES and Northrop in January 2009 but Risks to not achieve the requirements !
- If measured performances are not compliant, CNES could accept on case by case deviation in particular for low nadir angles (below 40°)

Argos-4 Schedule



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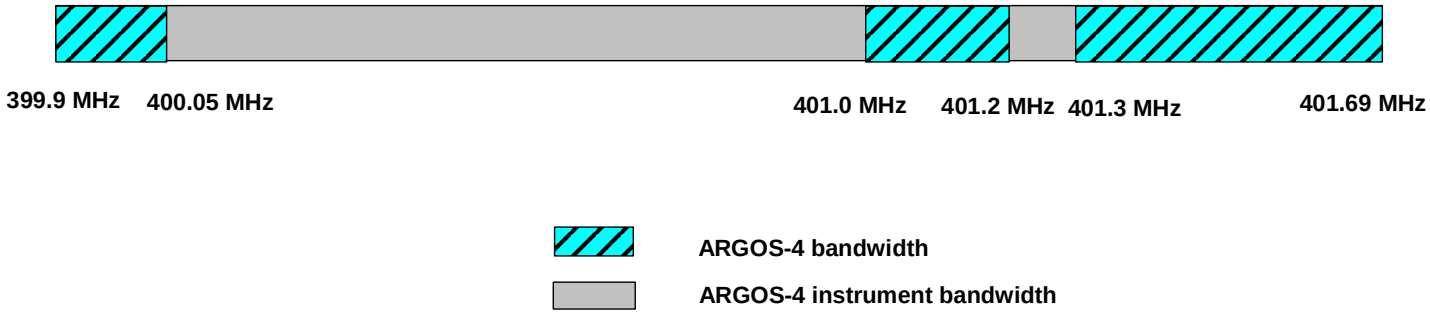
Overview of the Argos-4 System

Argos-4 Frequencies : uplink

- **Uplink (Earth to Space): Argos-4 system uses the following sub-bands compliant with the frequency coordination**
  - **[399,9 – 400,05] MHz**
  - **[401,0 – 401,2] MHz**
  - **[401,3 – 401,69] MHz**



Argos-4 Frequencies

- **Downlink (Space to Earth) : considering the NOAA N' concern about the frequency agreement at 465.9875 MHz above US and American territories, decision for Argos-4 to have the on board capability to select the downlink frequency among two possible values: 465.9875 MHz and 468.875 MHz**
  - **Frequency value could be chosen by command but probably defined at the latest on the launch pod or during the commissioning phase**
  - **If no FCC and NTIA agreement is given for Argos-3 on NOAA N' concerning the 465.9875 MHz frequency, Argos-4 system should have to use the back-up frequency at 468.875 MHz**

Potential impact on the platform receiver for Argos-4: capability to receive both frequencies at 465.9875 MHz and 468.875 MHz

Argos-4 platforms

Type of Platform	Low data Rate ARGOS-2	Low data Rate ARGOS-3	Very Low Data Rate ARGOS-4	High Data Rate ARGOS-3	High Data Rate ARGOS-4
Notation	BD-A2	NG-A3	VLD A4	HD-A3	HD- A4
Output Power (W)	≤ 3	≤ 2	≤ 0.5	≤ 5 ± 0.5	≤ 3
Modulation	PCM/PM	QPSK	PCM/PM	GMSK-BT=0.5	GMSK-BT=0.5
Useful Data Rate (bps)	400	400	100	4800	1200 and 4800
Channel Coding	NON	CV (7, 1/2)	CV (7, 1/2)	CV (7, 3/4)	Turbo Code, Rate 1/2
Minimum C/No (dB.Hz)	37	34	30.5	48	38 for 1200 bps 44 for 4800 bps
Pure carrier preamble	160 ms	82 ms	160 ms	82 ms	82 ms

Argos-4 Platforms

- **New High Data Rate platform – HD-A4**
  - **Needed to improve the multiple access performance with industrial noise and interferers for high data rate platforms**
  - **Designed to get better performances in unique access compared with the High Data Rate ARGOS-3 platform**
    - For the same useful data rate at 4800 bps (9600 symbol/s), the minimum signal power to noise density ratio required with HD-A4 platform is lower than HD-A3 – gain of 4 dB
  - **Support two data rates : 4800 bps and 1200 bps (9600 symbol/s)**
    - The same modulation scheme supports both data rates. In the case at 1200 bps, there is an additional bit coding (efficiency of 1/4) before channel coding
    - Data rate commutation is managed inside the platform by means of uplink C/N0 measurement provided with the acknowledgement on the downlink channel by A-DCS
      - When C/N0 is high (no interferer and quiet areas) HD-A4 platform switches to 4800 bps data rate
      - When C/N0 is lower (noisy areas with interferers) uses the medium data rate at 1200 bps
  - **By reducing the useful data rate in noisy areas**
    - the access probability is improved due to the spectrum occupancy reduction (reduction of the frequency and time collision probability)
    - the link budget is improved (more bursts can be recovered during a pass)

Argos-4 Platforms

- **Very Low Data Rate platform – VLD-A4**
  - **Needed to improve the multiple access performance with industrial noise and interferers**
  - **Designed to be compatible with the animal tracking applications needs (low output power, low consumption, small size and mass)**
    - Modulation scheme very simple
    - Heritage of the BD-A2 : modulation PCM/PM
    - With the same channel coding as NG-A3
    - Data rate at 100 bps
  - **Only PTT version (no receiver capability)**

Argos-4 Downlink Channel

- **The downlink modulation scheme is designed in order:**
  - **To be compatible with the Argos-3 Downlink**
  - **To assure the same power flux density as Argos-3 despite an increase of 3 dB of the on board output power**
  - **To reduce as much as possible the cost of the platform by keeping a simple receiver architecture**
- **The downlink is split into two channels:**
  - **Channel 1: the same modulation as Argos-3 with data rate at 400 bps**
  - **Channel 2: Phase modulation with subcarrier modulation at 4800 Hz and data rate at 800 bps**

Argos-4 Downlink Channel

- The space-to-earth link:
  - Same as the Argos-3 downlink with a larger bandwidth:

  Frequency range : 465.9775 – 465.9975 MHz, Bandwidth = 20 kHz, EIRP = 40 dBm
  - The Argos-4 downlink has been designed in order to be compliant with the Argos-3 downlink,

Argos-4

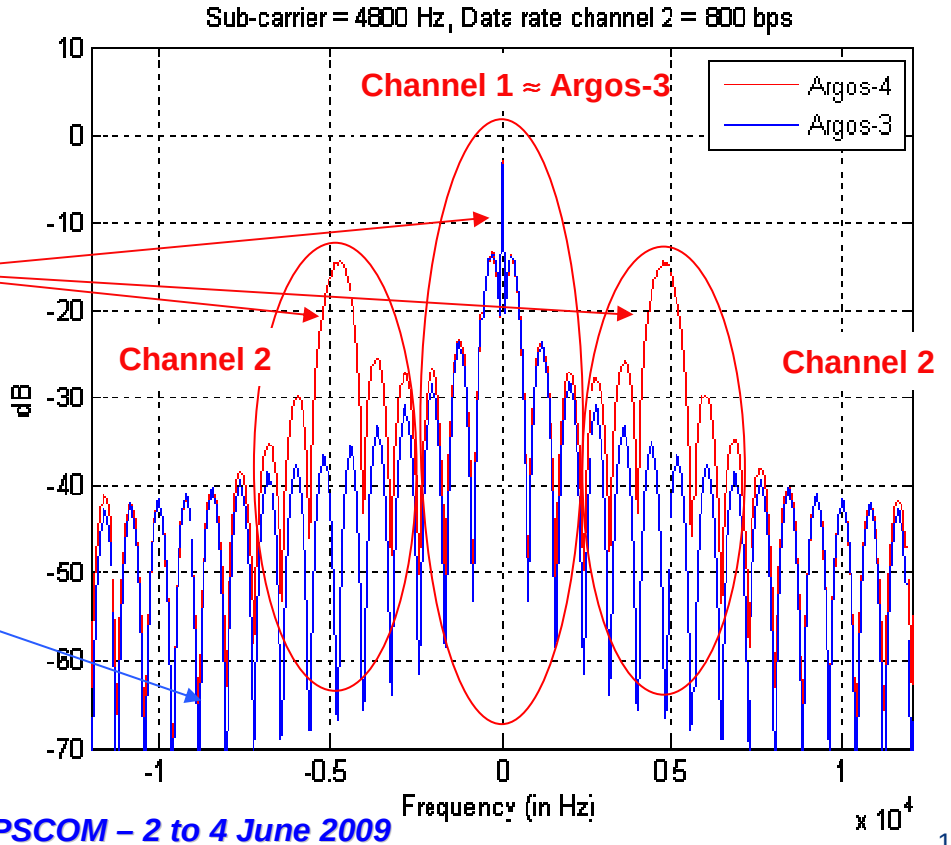
→ Channel 1 = 400 bps

→ Channel 2 = 800 bps

Downlink capacity with Argos-4 = 1200 bps

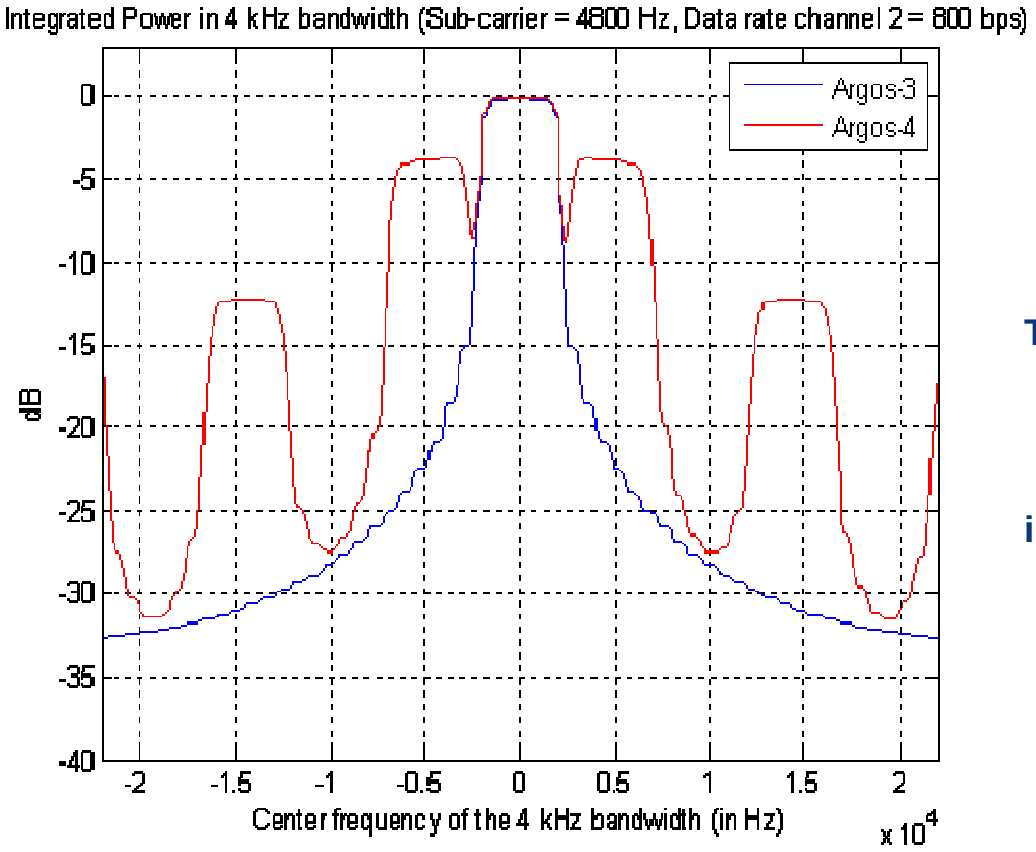
Argos-3

(400 bps)



Argos-4 Downlink Channel

The Argos-4 downlink has been designed in order to have the same power flux density at ground as Argos-3



The maximum of the integrated power in 4 kHz

is similar to Argos-3 → the power flux density

in 4 kHz bandwidth at ground level is the same as Argos-3 in spite of a 3 dB increase power.

Argos-4 System Capacity

- **First step: computation done without interferer taking into account of the on board instrument architecture**
  - **Argos-4 bandwidth divided into elementary bands of 80 kHz**
    - 3 sub-bands for High Data Rate Applications
    - 5 sub-bands for Low Data Rate Applications
  - **Feasibility of the Argos-4 instrument requires maximum 8 modems (also called UT) for high data rate processing**
- **Second step: computation done taking into account the interferers**
  - **The impact of the interferers depends on the geographical area and the frequency bandwidth (worst case in Europe)**
    - Extra modems required to achieve the same multiple access probability
    - Sometimes reduction of the system capacity when the number of modems are limited (in the case of High Data Rate applications)

Argos-4 System Capacity

System capacity for Low Data Rate applications

Worst case jamming in Europe	Low Data Rate Applications				
Frequency bandwidth (MHz)	**399,9 - 400,05**	**401,0- 401,1**	*401,3 - 401,38 (1) (2)*	**401,1- 401,2 (2)**	**401,61 - 401,69**
Modems required without jamming (> 65%)	6	7	*4*	4	7
Total number of modems without jamming	**28,00**				
System capacity per bandwidth (Erlang)	5,0	5,3	*3,1*	3,2	5,4
Total capacity for ARGOS-4 without jamming (Erlang)	**22,00**				
Modems required with jamming (> 65%)	**6**	**8**	*4*	**5**	**9**
Total number of modems with jamming	**32,00**				
System capacity per bandwidth (Erlang)	**3,0**	**5,3**	*3,1*	**3,2**	**5,4**
Total capacity for ARGOS-4 with jamming (Erlang)	**20,00**				

Notes: (1) no jamming inside this sub-band

(2) VLD-A4 platforms inside this sub-band dedicated to low power applications

Argos-4 System Capacity

System capacity for High Data Rate applications

Worst case jamming in Europe	High Data Rate Applications	
Frequency bandwidth (MHz)	**401,38 - 401,53**	**401,53 - 401,61**
Modems required without jamming (> 65%)	**5**	**3**
Total number of modems without jamming	**8,00**	
System capacity per bandwidth (Erlang)	**2,5**	**1,5**
Total capacity for HD ARGOS-4 (Erlang)	**4,00**	
Modems required with jamming (> 65%)	**5**	**3**
System capacity per bandwidth (Erlang)	**2,2**	**1,1**
Total capacity for HD ARGOS-4 with jamming (Erlang)	**3,3**	

Note: No HD-A3 in Europe and HD-A4 set at 1200 bps in Europe because of jamming

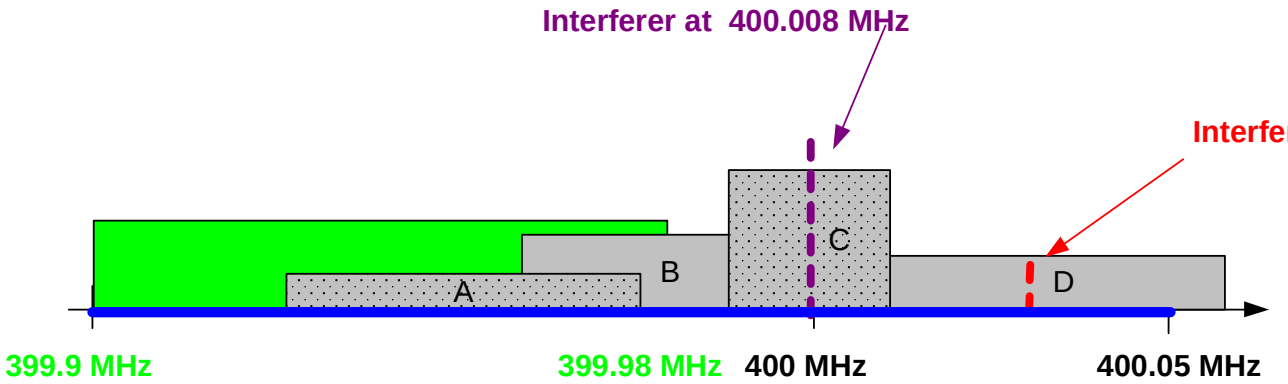
Argos-4 System Capacity

System capacity comparison between Argos-3 and Argos-4

Parameter	ARGOS-3		ARGOS-4	
Type of applications	High Data Rate	Low Data Rate	High Data Rate	Low Data Rate
Number of platforms seen per day	no user platform deployed	10,000 platforms (OPSCOM 2008)	3,675 platforms	23,580 platforms
On board instrument Bandwidth	30 kHz	80 kHz	230 kHz	400 kHz
	Total 110 kHz		Total 1,79 MHz including 630 kHz for platforms traffic	
Peak capacity with multiple access probability better than 65% (without jamming)	0.7 E	7.6 E	4 E	22 E including • 5 E for Non Environmental • 6.3 E for low power platforms
Number of modems	3	9	8	32

Argos-4 Applications Allocation

1 - Non Environmental Applications



Narrow band Interferers in Asia (< 5 kHz)

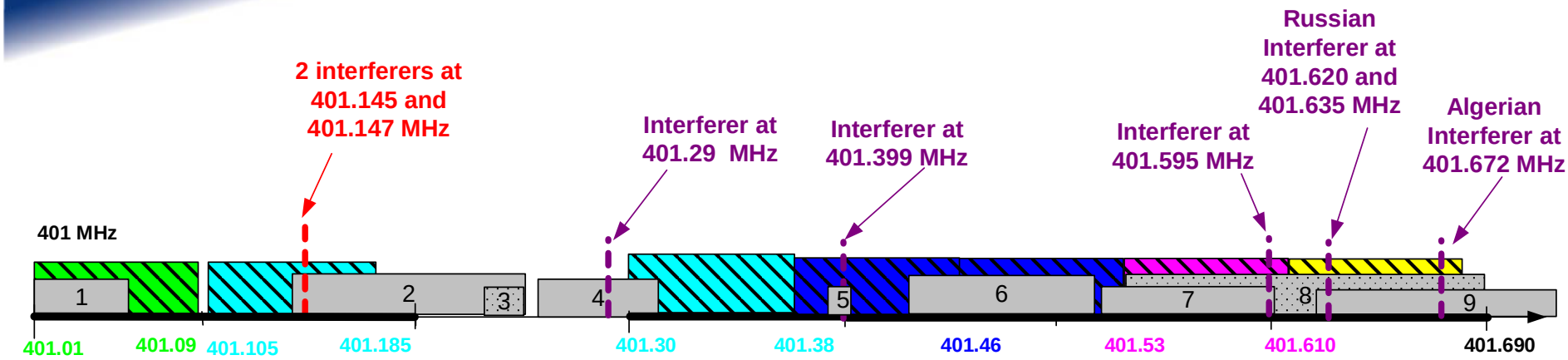
Low data rate ARGOS 4 platforms

Frequency bandwidth under coordination

Main Interferers in Europe

- Narrow band (< 5 kHz)
- Broadband

2 - Environmental Applications



Legend : ARGOS 3 & 4 applications

- High data rate ARGOS 4 & ARGOS-3 platforms
- High data rate ARGOS 4 platforms
- Low data rate ARGOS-3 platforms
- Low data rate platforms with low output power (< 500 mW)
- Low data rate platforms with nominal output power

Narrow band Interferers in Asia (< 5 kHz)

Main Interferers in Europe

- **Narrow band (< 5 kHz)**
- **Broadband**

Frequency bandwidth coordinated for ARGOS-4

Argos-4 Link Budgets

- Update of the uplink budgets, computed at minimum 5° elevation angle
  - Taking into account a whip antenna for the platform
  - Taking into account the on board antenna gain
  - Including the industrial noise in Europe
  - See results in next slide
- Update of the downlink budget, also computed at minimum 5° elevation angle
  - System margin of 2 dB for channel at 400 bps
  - System margin of 0 dB for channel at 800 bps

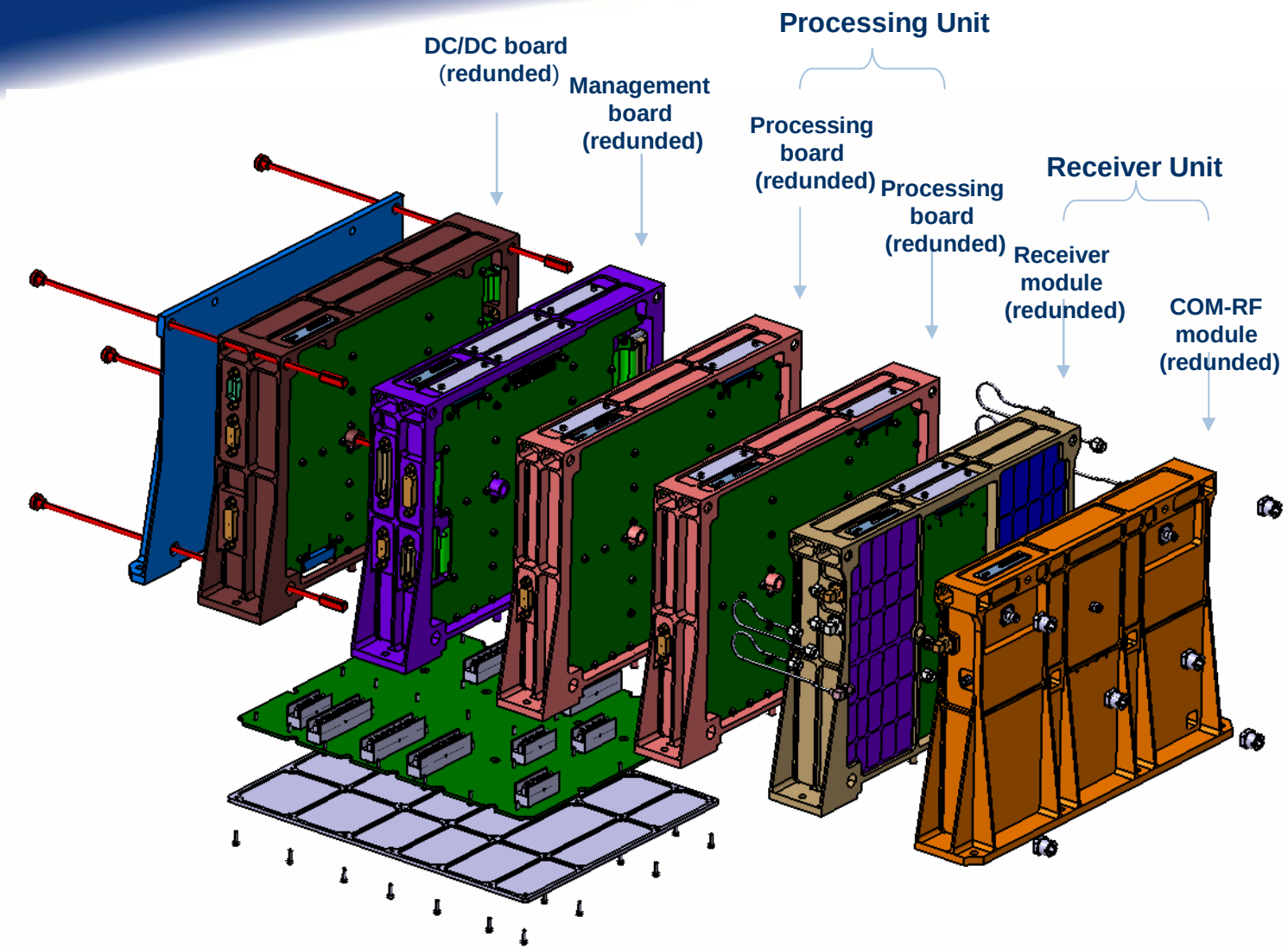
Argos-4 Link Budgets

Uplink system margins

Type of platform	A2	NG A3/ZE	HD A3	HD A4		VLD A4
Output power	2 W	1 W	5 W	3 W		500 mW
Useful data rate	400 bps	400 bps	4800 bps	4800 bps	1200 bps	100 bps
Without industrial noise						
Margin for unique access probability of 99%	6,6 dB	6,6 dB	-0,4 dB	1,4 dB	7,4 dB	7,1 dB
Margin for required BER	6,1 dB	7,8 dB	-0,2 dB	2,6 dB	8,6 dB	7,1 dB
With industrial noise (Europe case)						
Margin for unique access probability of 99%	3,6 dB	3,6 dB	-3,4 dB	NA	4,4 dB	4,1 dB
Margin for required BER	3,1 dB	4,8 dB	-3,2 dB		5,6 dB	4,1 dB

Better is the on board antenna gain and coverage, better are the system margins and the overall Argos-4 capacity

Argos-4 Receiver Processing Unit



Argos-4 Transmitter Unit